In-Space Networking On NASA's SCAN Testbed

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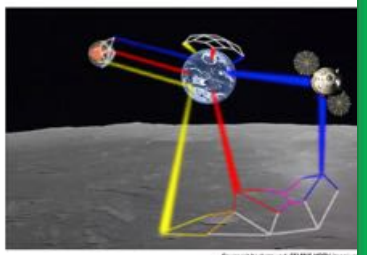
Agenda

- Motivation and Goals/Objectives
- Overview of SCaN Testbed
- Design Implementation Details
- Software Instrumentation
- Summary and Future Work

Motivation

Report of the
Interagency Operations Advisory Group
Space Internetworking Strategy Group

Recommendations on a Strategy for Space Internetworking
November 15, 2008



CCSDS
The Consultative Committee for Space Data Systems

Report Concerning Space Data System Standards

SOLAR SYSTEM INTERNETWORK (SSI) ARCHITECTURE

INFORMATIONAL REPORT

CCSDS 730.1-G-1

GREEN BOOK
July 2014

SPACE COMMUNICATIONS AND NAVIGATION PROGRAM

Space Communications and Navigation (SCaN)
System Requirements Document (SRD)

Revision 3

Effective Date: September 29, 2014

Expiration Date: September 29, 2019

NASA Headquarters
Washington, D. C.

CHECK THE SCaN NEXT GENERATION INTEGRATED NETWORK (NGIN) AT:
https://scanpo.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

458-REQ-0002

458 / SPACE NETWORK GROUND SEGMENT SUSTAINMENT PROJECT

Space Network (SN) Ground Segment Sustainment (SGSS) System Requirements Document (SRD)

Revision 1 w/DCN 009

Effective Date: June 23, 2011

Expiration Date: June 23, 2016

Goddard Space Flight Center
Greenbelt, Maryland

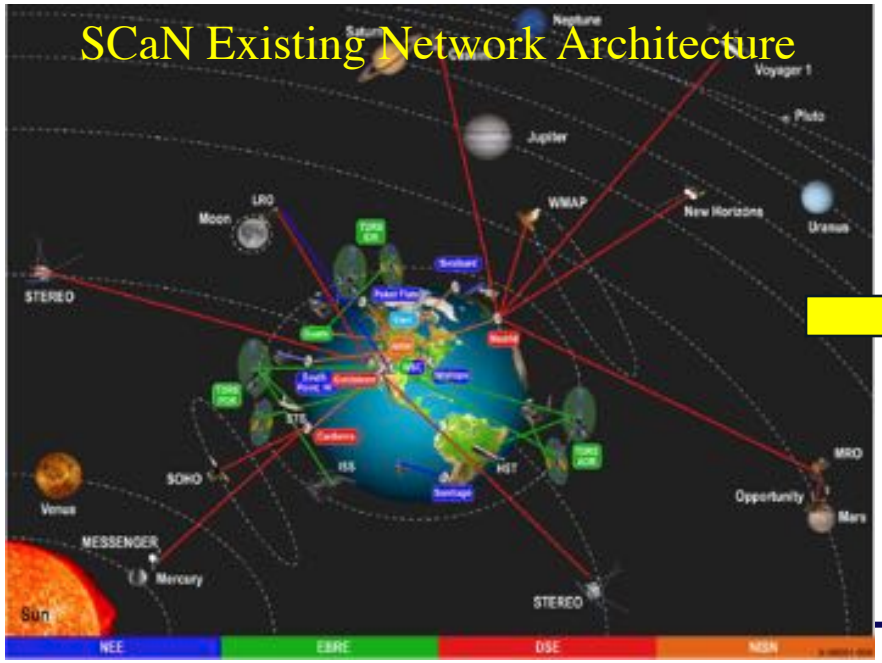
CHECK THE GSFC NEXT GENERATION INTEGRATED NETWORK (NGIN) AT:
https://codef0tgsa.gsfc.nasa.gov
TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

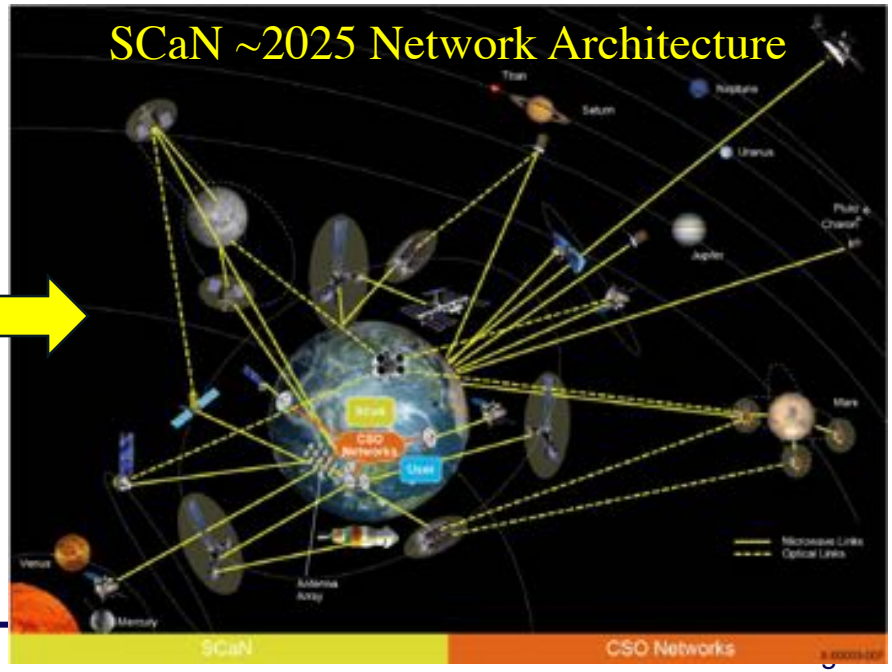
SGSS Requirements:
CCSDS AOS Protocols
Return AOS Frames
Forward AOS Frames
Forward Service ENCAP Processing
Return Service ENCAP Processing

SCaN shall "provide Space Internetworking services to mission users" and "interoperate with external space networks that are compliant with space internetworking standards."

Solar System Internet Implementation Challenges

- Requires protocol support across mission-developed and SCaN elements
- Limited number of reusable flight or ground software components
- Necessary standards still under development
- Commercial IT products do not support space mission needs
- Different operations concept between networking and legacy point-to-point communication services.

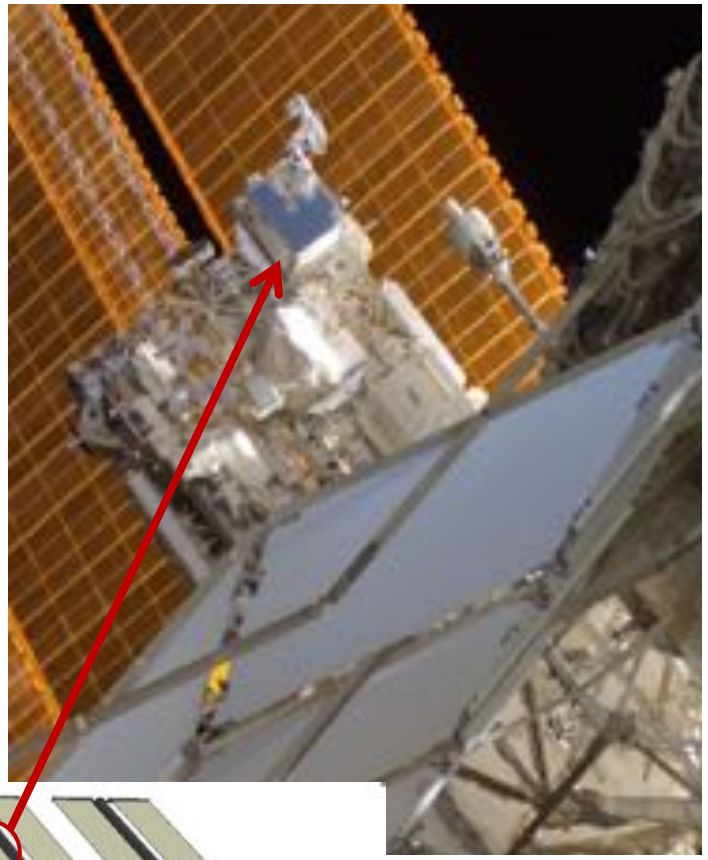


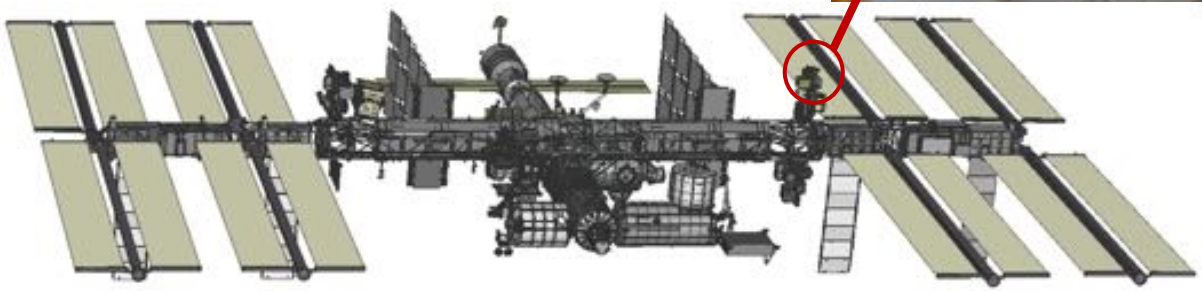


Goals and Objectives

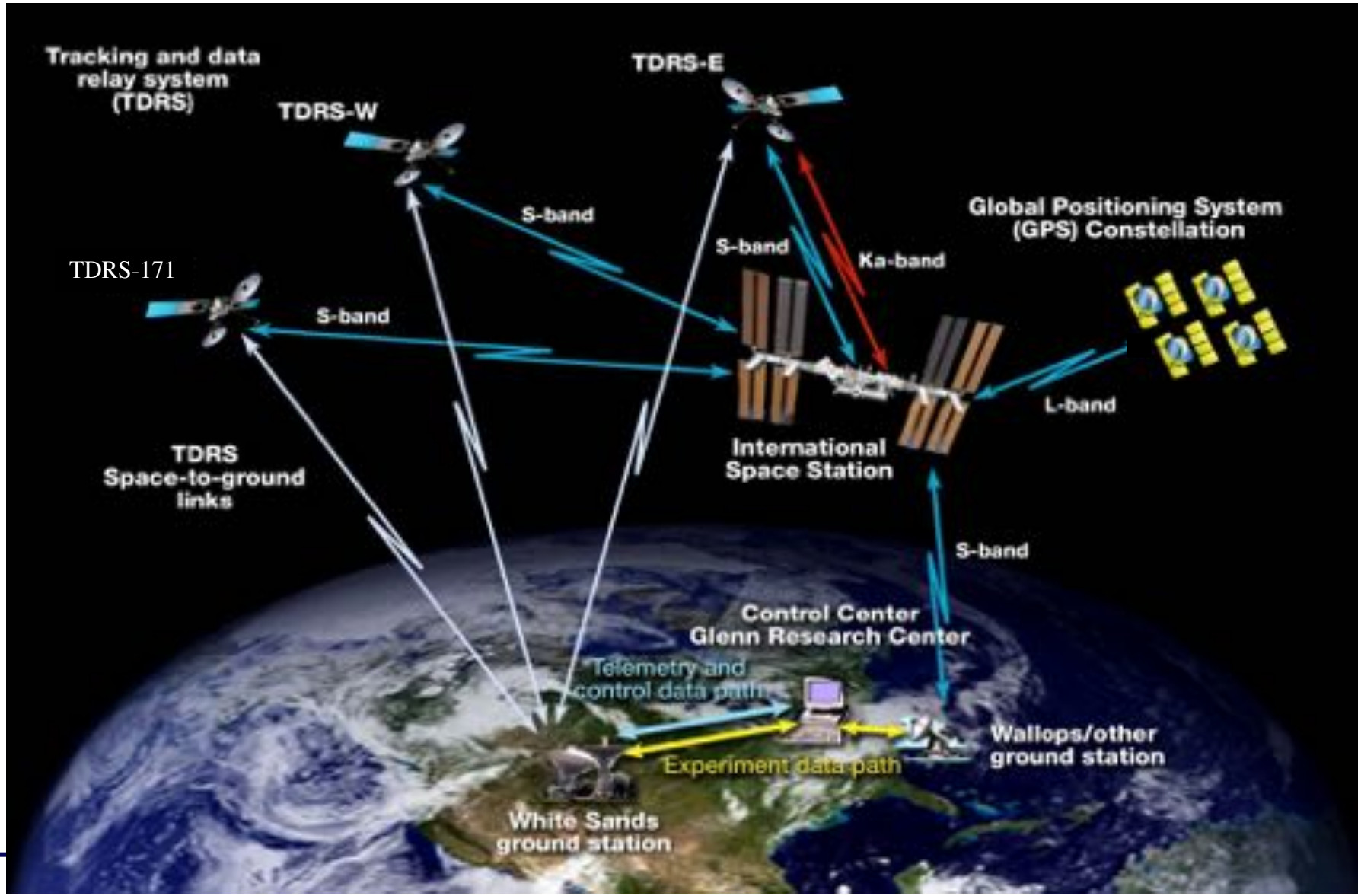
SCaN Testbed Networking Portfolio

- Gain long-term operations experience with Space Internet
- Produce robust, flexible implementations for future missions
- Support network topologies that represent future mission complexity
- Mature the operational concept
- Integrate networking with realistic on-board data interfaces
- Include native support for security protocols operating across multiple layers





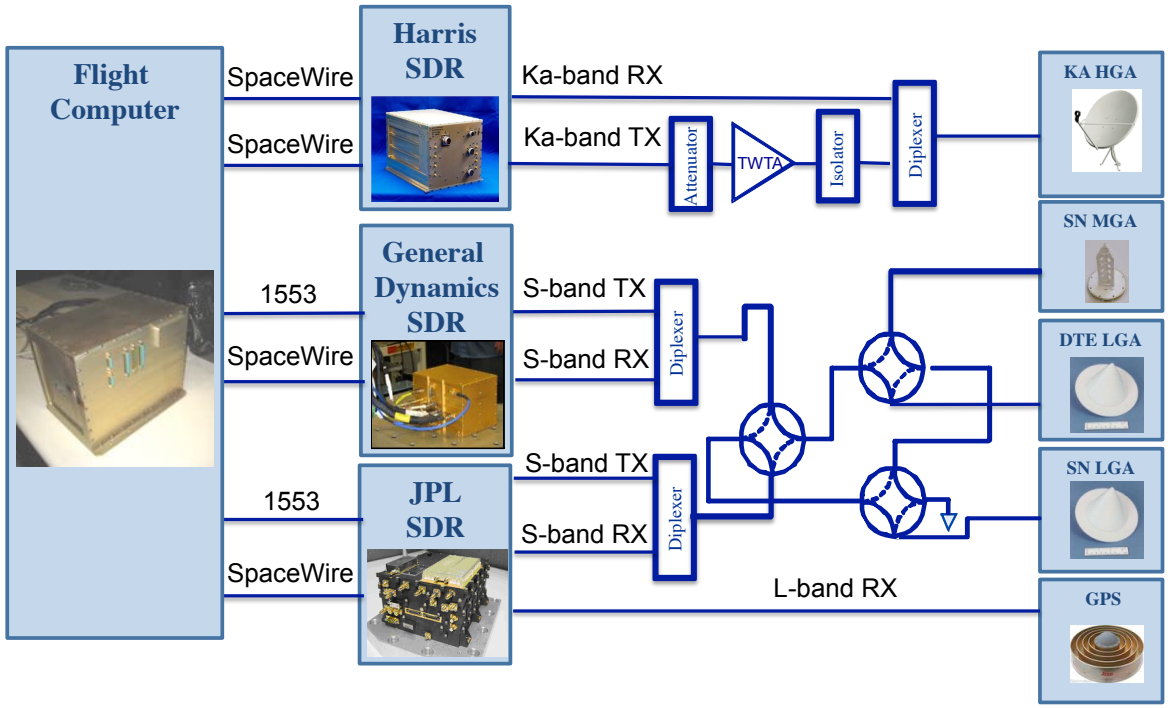
SCaN Testbed System Overview - Architecture



SCaN Testbed Overview - Flight System & Initial Capabilities

Comprehensive testing of:

- Ability to perform on-orbit updates
- RF and physical layer development platform
- Point-to-point physical and bit layer services between Software Defined Radios and Mission Operations Center
- Command and telemetry services

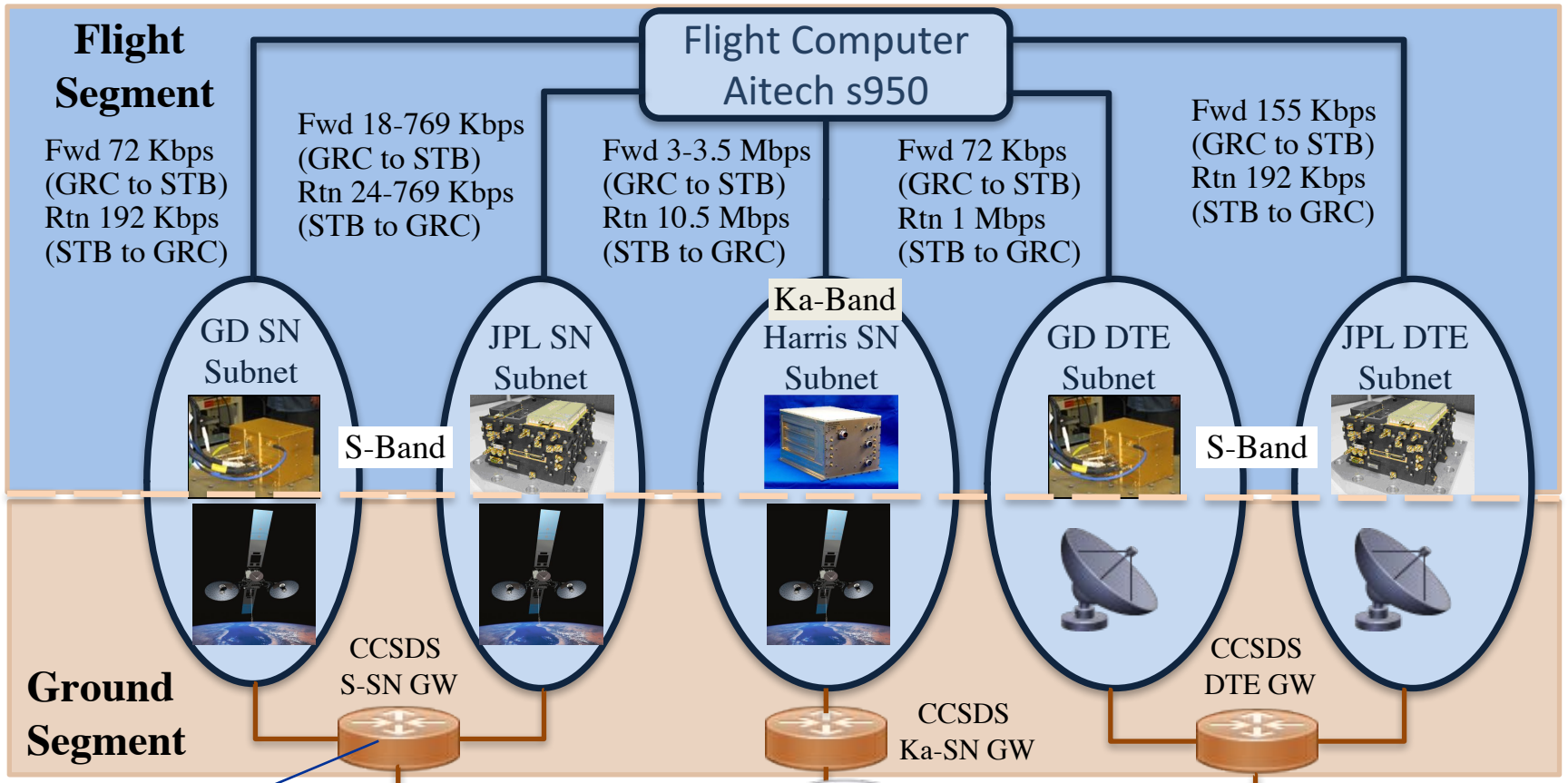


Launch Software Capabilities

- Launch waveforms: Compatible with the TDRS Space Network. Limited CCSDS Advanced Orbiting System (AOS) implemented.
- Avionics software: Focus on system control.

Launched with minimal software to meet schedule constraint

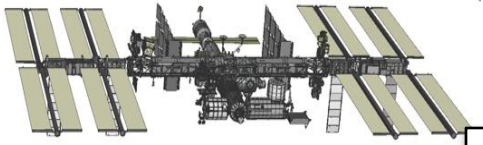
Baseline Network Point to Point Links Overview



Ground gateways exchange CCSDS AOS Transfer Frames, IP and Encapsulation Packets with flight gateway. IP packets are exchange with ENCAP Internet Protocol Extension.

Ground computer exchange CCSDS AOS Transfer Frames, Internet Protocol packets and Encapsulation Packets with the three ground gateways.

Reusable Software Components



Ground Test Tools Applications OS Provided Services

ENCAP Network Interface for VCID/SCID TF (Kernel Module)

User space AOS TF Injection app

PHY Link Sync Serial to User space AOS TFs (Kernel Module)

Ground Station/ MOC
Linux / x86-64

COTS Apps
EPING
CFDP
BP / BPsec
LTP-UDP
TCP/UDP
IPsec
IPv4/IPv6
IPE
LTP
PRIV
ENCAP
AOS

Space Network

SYNC & CODING
RF

Flight Computer
VxWorks / PowerPC

COTS Apps
CFDP
BP / BPsec
LTP-UDP
TCP/UDP
IPsec
IPv4/IPv6
IPE
LTP
PRIV
ENCAP
AOS

SDR / FPGA

SYNC & CODING
RF

VxWorks Application ports: ION, ping, httpd, iperf

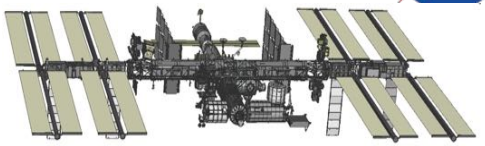
Service Loopback

ENCAP to MUX Kernel Module

AOS-ENCAP Convergence Tasks

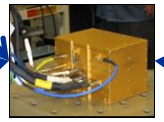
TDRSS-compatible waveform

Software Instrumentation



Experiment Front End Processor

SN Statistics



Flight Computer

CCSDS GW

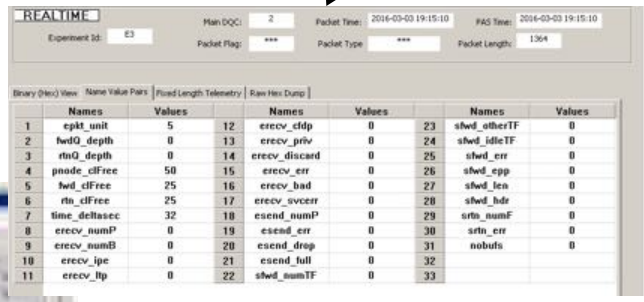
- Loggable CCSDS Statistics (ENCAP and AOS) in user space
- CCSDS ENCAP capture using COTS libpcap and tcpdump
- eping test application for ENCAP RTT and link errors

GRC GS

GS Statistics
Tracking
Power Levels
Modem (TSIM)

FS and SDRs
- Physical Link
- Tracking
- Health and Status
- Waveform Status

(Primary Path)



Encapsulation Packet Statistic @CCSDS GW:
- Number Received/Sent through GW
- Number of various Errors such as bad length, invalid ENCAP header, etc..

=>Readable in user space as a file

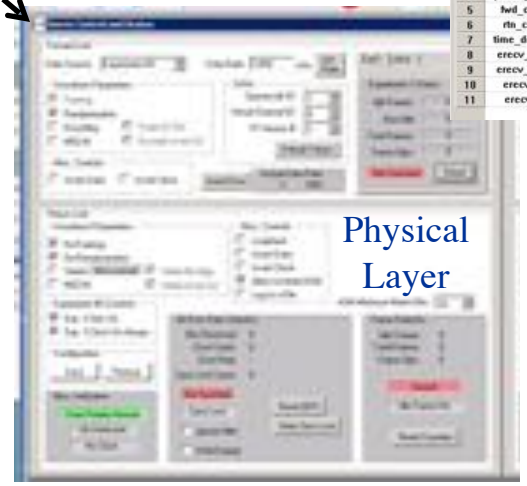
Data Flow

Experimenter Machine

- ICMP "ping" for RTT
- Ethernet packet capture
- ION Applications

Synchronous Serial AOS Statistics@CCSDS GW:
- Number AOS TFs Received/Sent through GW
- Various Errors such as bad length, dropped frames

=>Readable in user space as a file



Physical Layer

Networking/Flight SPW and ENCAP Stats (Primary Path APID)

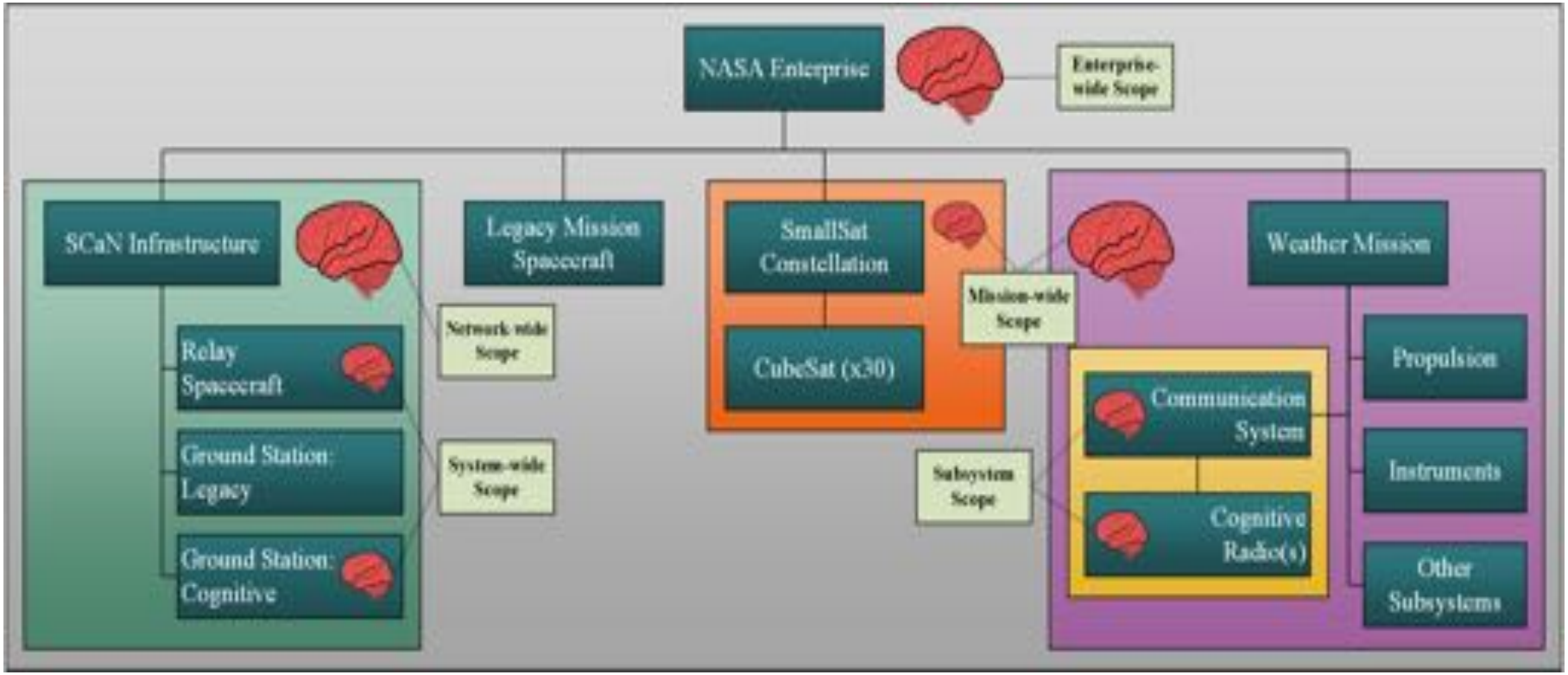
Experiment Path Stats (currently work/NITRO)

Conclusion and Future Work

- **SCaN Testbed networking implementation and knowledge gained will enable NASA's transition to Solar System Internet. This include demonstrating IPv4 routing on a CCSDS reusable ground and flight software components that served to:**
  - **Produce a robust, flexible implementations for future missions**
  - **Create a baseline topology with CCSDS that integrates with future complex missions**
  - **Help to mature the operational concept by integrating CCSDS with a space testbed**
  - **Integrate networking with realistic space on-board data interfaces (Spacewire)**
  - **Include native support for security protocols operating across multiple layers (Secure DTN)**

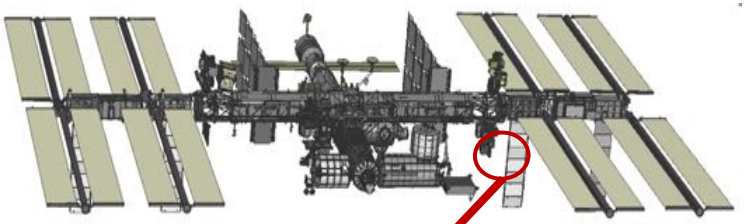
Conclusion and Future Work

- **Foundation has been laid for cognitive networking capabilities research and development activities such as NASA Intelligent Routing(NITRO), Cognitive Networking(COGENT) and SCaN Testbed that evolves to Cognitive Communication project**



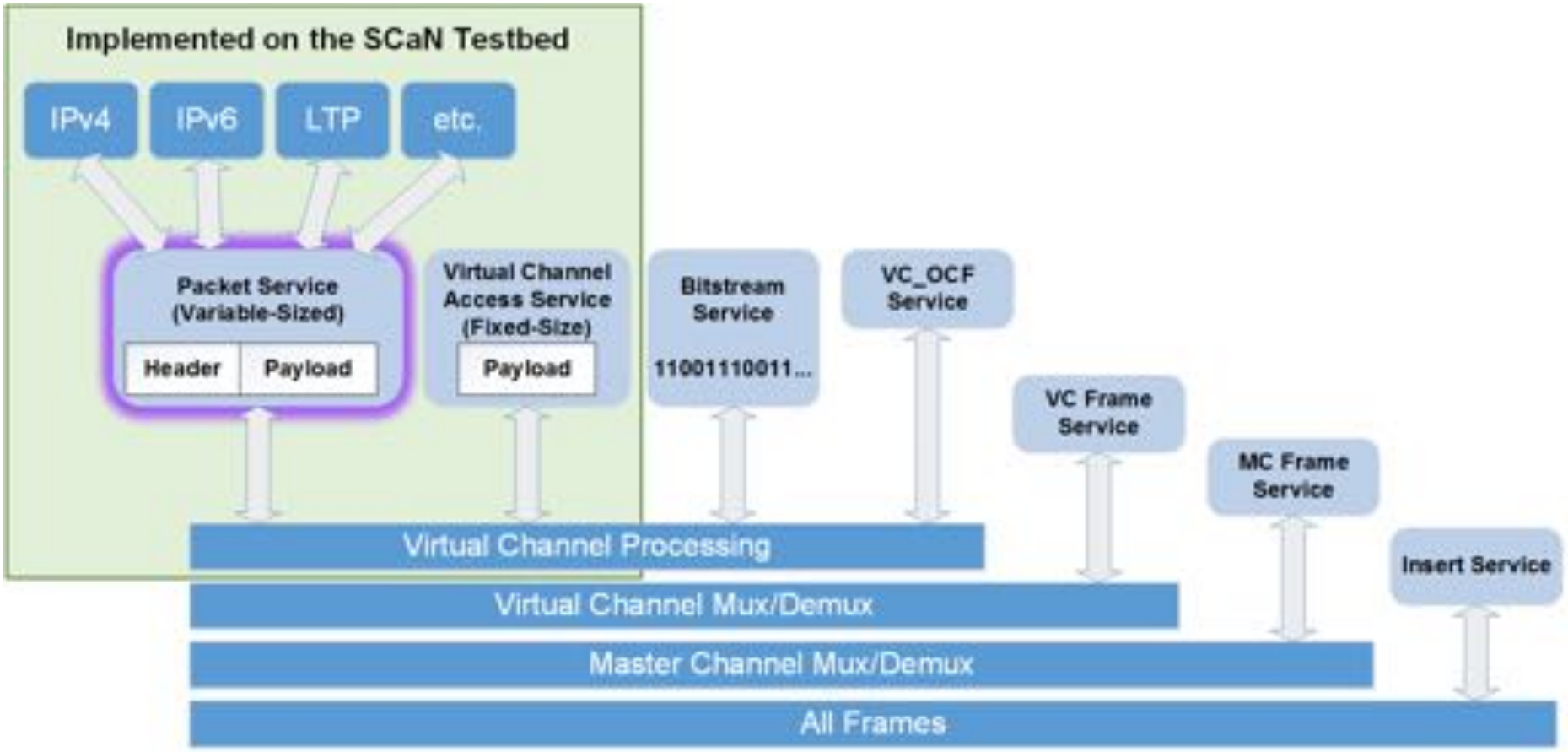
Space Protocol Research on the SCaN Testbed

Application	CCSDS 734.2-R-3 CCSDS Bundle Protocol Specification	Network Management Protocol Key Distribution Protocol Bundle Protocol Security (BPsec)
Transport	CCSDS 727.0-B-4 CCSDS File Delivery Protocol	CCSDS 734.1-B-1 (LTP)
Network	CCSDS 702.1-B-1 IP over CCSDS Space Links	CCSDS 133.1-B-2 Encapsulation Service
Data Link	CCSDS 131.0-B-2 TM Synchronization and Channel Coding	CCSDS 732.0-B-2 AOS Space Data Link Protocol
Physical	CCSDS 131.3-B-1 CCSDS Space Link Protocols over ETSI DVB-S2 Standard.	CCSDS 131.5-M-1 Variable Coded Modulation Protocol
	CCSDS 401.0-B-25 RF Earth Stations and Spacecraft	CCSDS 415.1-B01 Data Transmission and PN Ranging for 2 GHz Link via Data Relay Satellite
Cross Support SLE	CCSDS 911.1-B-3 Space Link Extension—Return All Frames	CCSDS 912.11-0-1 SLE–Enhanced Forward CLTU
	CCSDS 911.2-B-2	CCSDS 912.1-B-3 SLE–Forward CLTU Svc
	CCSDS 911.5-B-2	CCSDS 913.1-B-1 SLE – IP for Transfer Svc



SCaN Testbed on ISS

AOS and ENCAP on SCaN Testbed



Acronym List

- AOS – Advanced Orbiting Systems
- BP– Bundle Protocol
- CCSDS – Consultative Committee for Space Data Systems
- CSO – Communication Service Office
- DSE – Deep Space Element
- DTE – Direct to Earth
- DTN – Delay Tolerant Networking
- EBRE – Earth-Based Relay Element
- ENCAP – Encapsulation
- Fwd – Forward service
- GRC – NASA's Glenn Research Center
- GS – Ground Station
- GW – Gateway
- ION – Interplanetary Overlay Network
- ISS – International Space Station
- LTP – Licklider Transport Protocol
- LTP – Liklikder Transport Protocol
- NASA – National Aeronautics and Space Administration
- NEE – Near Earth Element
- NISN – NASA Integrated Services Network
- NITRO – NASA Intelligent Routing
- OS – Operating System
- Rtn – Return service
- RTT – Round Trip Time
- SCaN – Space Communication and Navigation
- SGSS – Space Network Ground Segment Sustainment
- SN – Space Network
- SPW – SpaceWire
- STB – SCaN Testbed
- TDRS – Tracking and Data Relay Satellite
- TSIM – TDRS Simulator
- TF – Transfer Frame